Temperature Mapping in Human Brain Postmortem by MR Spectroscopic Imaging

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Introduction: Recently, virtual autopsy (virtopsy^{TM}), including postmortem MR imaging, has found great interest and has been introduced in forensic medicine [1-3]. An inherent problem of post mortem imaging is generated by the fact that the body temperature is lower than in living subjects and that the cooling (or warm-up after storage in a refrigerator) may be inhomogeneous, both leading to suboptimal contrast behavior if typical clinical imaging sequences are used. In order to optimize MR parameters for targeted image contrast at different body temperatures, the temperature dependence of water relaxation times must be known, requiring both, relaxation time measurements and corresponding absolute temperature estimation. Previously, it has been shown that absolute temperature measurements can be performed using MR spectroscopy (MRS) employing the temperature dependent frequency shift of the water line [4-7]. In this study we performed measurements of relaxation times and absolute temperature using MR spectroscopic imaging (MRSI). Main goals were: 1. to map the temperature in the postmortem brain by MRSI reliably, sufficient precise, and largely automated; 2. to compare the temperature obtained by MRSI in the brain with externally determined temperature; 3. to determine regional temperature differences in the brain (during cooling or warm-up).

Methods: Subjects: *In situ* MRSI of brain tissue was performed on five human bodies. Two subjects were scanned four times over a total period of ~11h. Previously the bodies were cooled to 6-14°C and than allowed to warm up. The bodies were wrapped in plastic sheeting slowing down the warming up. External temperature was recorded frequently by placing a thermometer under the tongue.

Measurements: Proton multisection MR spectroscopic imaging spectra were acquired at 1.5T (Signa, GE). Three 15-mm sections (10mm spacing) were acquired with angulation along the AC-PC line with the center section just including the corpus callosum. The equivalent of 24×24 phase-encoding steps over a circular k-space region was used. Eight saturation bands were used to suppress skull lipids. The data were acquired with TR/TE=2800/144msec. Weak water suppression was applied to retain sufficient signal for H_2O frequency determination. Scan time was 21 min.

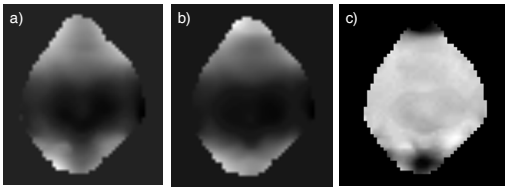

Fig. 1: Frequency offset map for Cr, Ch (a), H_2O (b) and the difference map, yielding a map that is directly proportional to the temperature.

Postprocessing included zero-filling to 64×64, mild spatial apodization, zero-filling to 4096 data points in time domain and apodization with a Gaussian function (2 Hz line-broadening). The frequency shift of the water line relative to creatine and choline resonances was determined automatically: The frequency offset was calculated at which the highest cross-correlation occurs between the water line from each voxel and a reference spectrum. The same procedure was repeated for the creatine / choline lines. The difference of the two frequency offsets is independent of B_0 inhomogeneities and can directly be converted to absolute temperature, using established relations between H_2O shifts and temperature [4,5].

Results: The procedure for automatic estimation of temperature maps is illustrated in Fig. 1. Overall, the difference map (Fig. 1c) shows low variations, corresponding to a relative uniform temperature. The spectral quality was very good over large areas in all three slices in all subjects (results not shown). Over the time period of the measurements the externally determined temperature rose linearly for the two subjects from 13-16°C and from 15.5-21°C, respectively. Comparing the externally determined temperature increase over time with the temperatures obtained in few voxels from all three slices, yielded a very high correlation for both subjects that were scanned four times (Fig. 2), although the temperature rose only by a few degrees. However, for one subject the temperatures measured in the brain were lower by ~2°C compared to the external determination in the mouth. Fig. 3 shows temperature traces through the middle of the brain of the center section for all four measurements in this subject. While the temperature in the center of the brain is slightly lower than closer to the skull in all four scans, overall only small differences are observed.

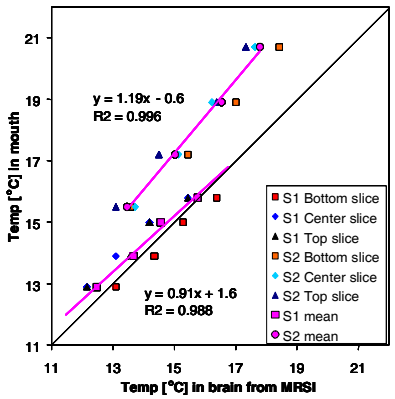

Fig. 2: Comparison between the manually determined temperature rise over time and the brain temperature from MRSI in two subjects measured 4 times during warm up.

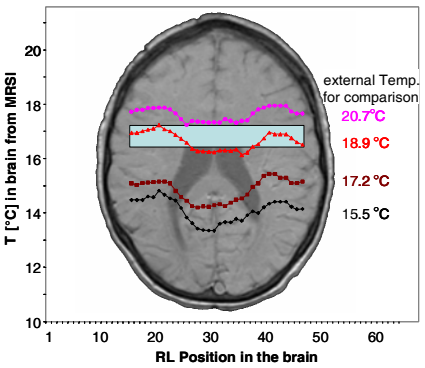

Fig. 3: Right-left temperature traces through the middle of the brain for all four scans in one subject at rising temperature. The traces were obtained from averaging four lines (indicated by the blue bar). An MRI is laid underneath demonstrating the trace position.

Discussion: The study clearly demonstrates the feasibility to obtain within 21 min scan time reliable and largely automated temperature maps covering large parts of the postmortem brain. Reasonably the technique is applicable also *in vivo*. The method appears sensitive to pick up also small temperature differences. The temperatures in the brain were highly correlated to manually determined temperatures in the mouth, though - as might be expected - slightly lower. This difference may be enlarged if a body is exposed to faster temperature changes. Only small temperature differences were measured within the brain in our experimental setting. Previously we have shown that besides temperature mapping MRS may assist in determination of the postmortem interval [8] and in analyzing metabolic decomposition. The MRSI data obtained in this study may in addition allow for a spatially resolved analysis of autolytic and bacterial brain processes after death. These measurements build the basis for determination of the temperature dependence of relaxation times in decomposing brain, and will also be analyzed for regional variations in metabolic decomposition.

References:

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